

Validation of the Ocean Component of PIPS3.0

Michael Steele

Applied Physics Laboratory

1013 NE 40th Street

Seattle, WA 98105-6698

phone: 206-543-6586 fax: 206-616-3142 email: mas@apl.washington.edu

Grant Number: N00014-99-1-0054

<http://psc.apl.washington.edu/Climatology.html>

LONG-TERM GOALS

Our long-term goal is to understand and model Arctic Ocean circulation. We do this by analyzing numerical model output as well as large hydrographic data sets, and comparing the two for model validation purposes. It has recently been recognized that the high latitude seas force changes in the world ocean circulation; we seek to understand this forcing and better model it.

OBJECTIVES

We had 2 specific objectives in this project, both in support of Navy modeling efforts. The Navy's new global ocean model, NCOM, is coupled to a sea ice model that has evolved from the PIPS2.0 sea ice component.

- (1) We sought to improve our hydrographic data base called the **P**olar science center **H**ydrographic **C**limatology, version 2.1, i.e., PHC2.1. We did this by: (a) filling "data holes" in the eastern Canadian arctic, (b) improving the monthly analytical function we use to temporally interpolate Russian data, and (c) enhancing the graphical interface on our web site, <http://psc.apl.washington.edu/Climatology.html>.
- (2) We also sought to better understand temporal change of the large-scale hydrographic fields in the arctic seas, in order to provide a baseline of such change for Navy modeling efforts.

APPROACH

Objective 1 (improving PHC): We improved the monthly cycloid function that we use to temporally interpolate seasonal Russian data from the Arctic Ocean Atlas (EWG, 1997 and 1998) to a monthly time scale. Specifically, we used an iterative technique to find the curve that makes the three-month averages for winter (JFM) and summer (JAS) consistent with the seasonal mean fields provided by the AOA. This illustrated in **Figure 1**. We also greatly improved the graphics available on the web site for surveying our data base. An example is provided in **Figure 2**.

Objective 2 (exploring temporal variability): We began by examining the variance plots provided by the AOA and by the World Ocean Atlas (WOA; Antonov et al., 1998; Boyer et al., 1998). We found that they are provided on different grids, and further, that AOA variances are provided on multiple grid

resolutions. The 2 data sets overlap in the Nordic Seas, where the variances generally match to zeroth order.

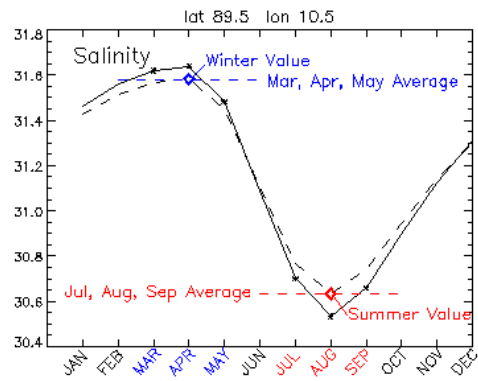


Figure 1. North Pole surface salinity, using a new analytical function to interpolate the AOA seasonal (winter=JFM, summer=JAS) data to a monthly timescale. The first-guess monthly time series (dashed curve) uses the seasonal values as extrema, which are then modified (solid curve) to ensure that the 3-month means of the monthly function are equal to the original seasonal values.

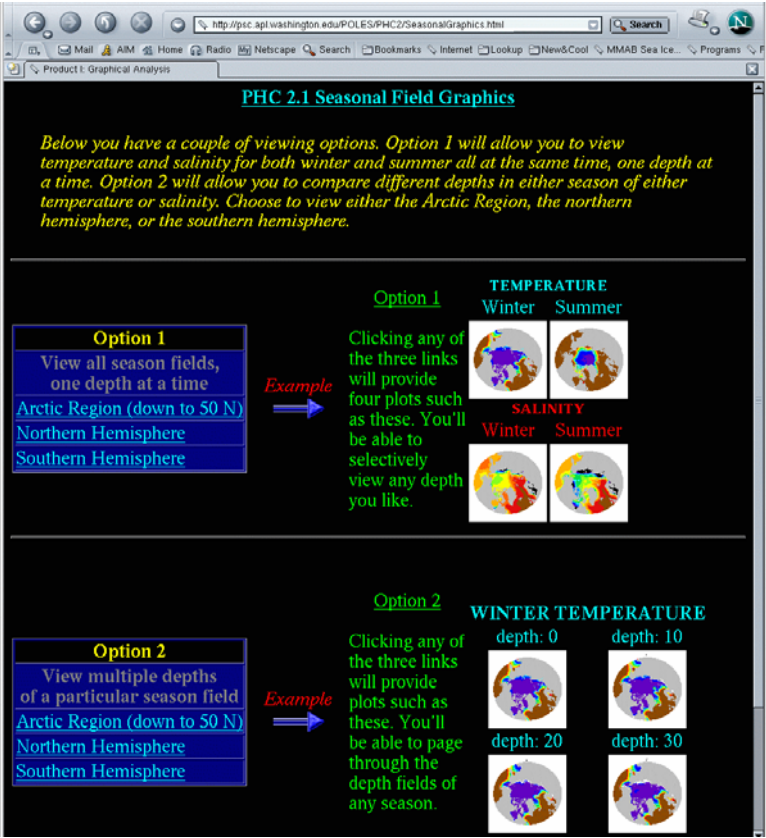


Figure 2. An example of the new graphical capabilities of the PHC2.1 web site. Shown here is the start page for viewing horizontal slices of the seasonal (winter and summer) data. One can choose to look at temperature or salinity for the northern or southern hemisphere, or just for the “arctic region” north of 50 degN. One can choose Option 1: view all season fields (T and S, winter and summer), one depth at a time, or Option 2: view multiple depths of a particular season’s field.

We next decided to examine the original profile data (i.e., ungridded and unsmoothed) in the WOA in order to examine long-term trends in these hydrographic data. The idea is that trends have been detected in large-scale climate indices (such as the North Atlantic Oscillation) and that such behavior will be expressed as a variance relative to the mean of our hydrographic data. We would like to distinguish between shorter term variance and longer term trends.

Figure 3 shows all of the data available from the latest World Ocean Database (WOD'01) from the National Oceanographic Data Center. The longest time series are from the Nordic Seas and from the continental shelves, while relatively fewer data are available (in this database) from the central Arctic Ocean. This motivated us to focus on the arctic shelves. Others, especially Europeans, are focusing on long-term trends in the Nordic Seas.

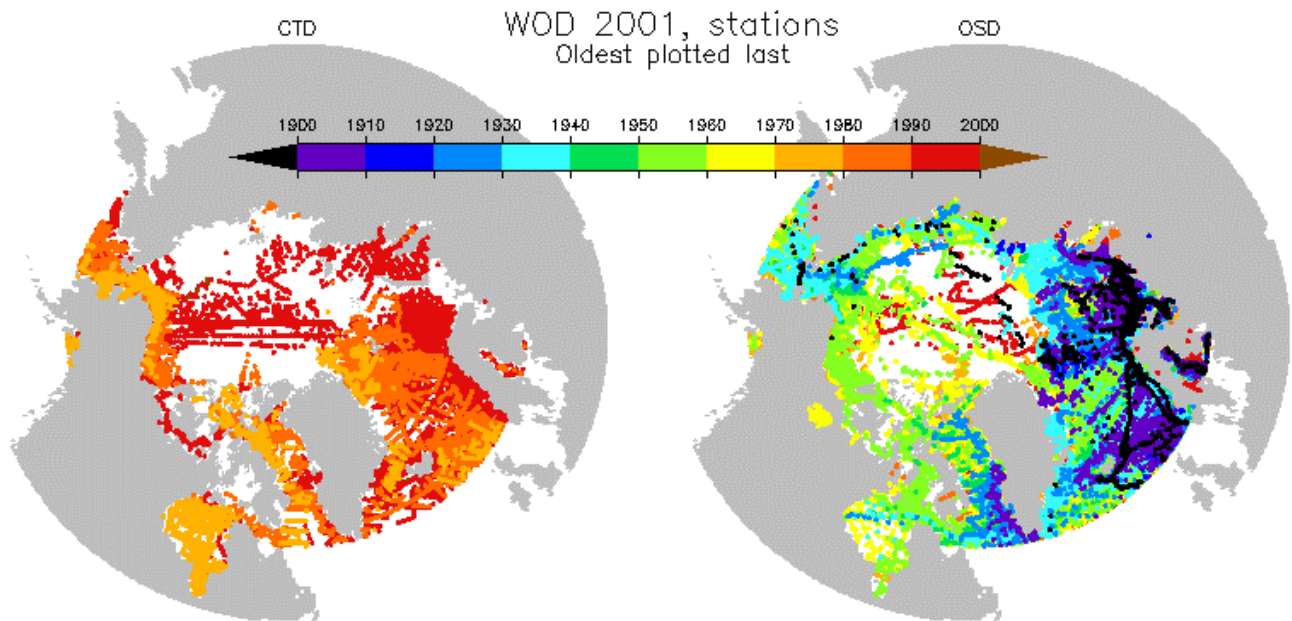


Figure 3. All temperature and salinity data locations north of 60 degN from the 2001 version of the World Ocean Database (WOD), ranked by decade from pre-1900 to the present. The left panel shows CTD data, which are available starting in the 1970's. The right panel shows "ocean station data" which includes data collected by bottles, XBT's, and other older technologies. The longest time series are available from the Nordic Seas and from the continental shelves.

We first sought to find trends within 200 km grid boxes, with the hope of creating a contour map of such trends. Unfortunately, the result is noisy and rarely produces statistically significant trends. We next decided to average the data into physically based regions, i.e., separate shelf seas such as the Kara Sea, the Laptev Sea, the East Siberian Sea, etc. This produces a better result, i.e., more significant trends. We have looked at a variety of time periods which all end in the present, i.e., 1850-present, 1930-present, 1950-present, 1970-present, and 1980-present. We recognize that there are potential decadal and longer oscillations; however, this is not our present focus. An example is shown in **Figure 4**, which presents only the areas with statistically significant trends in the salinity of the upper 10 m of the water column.

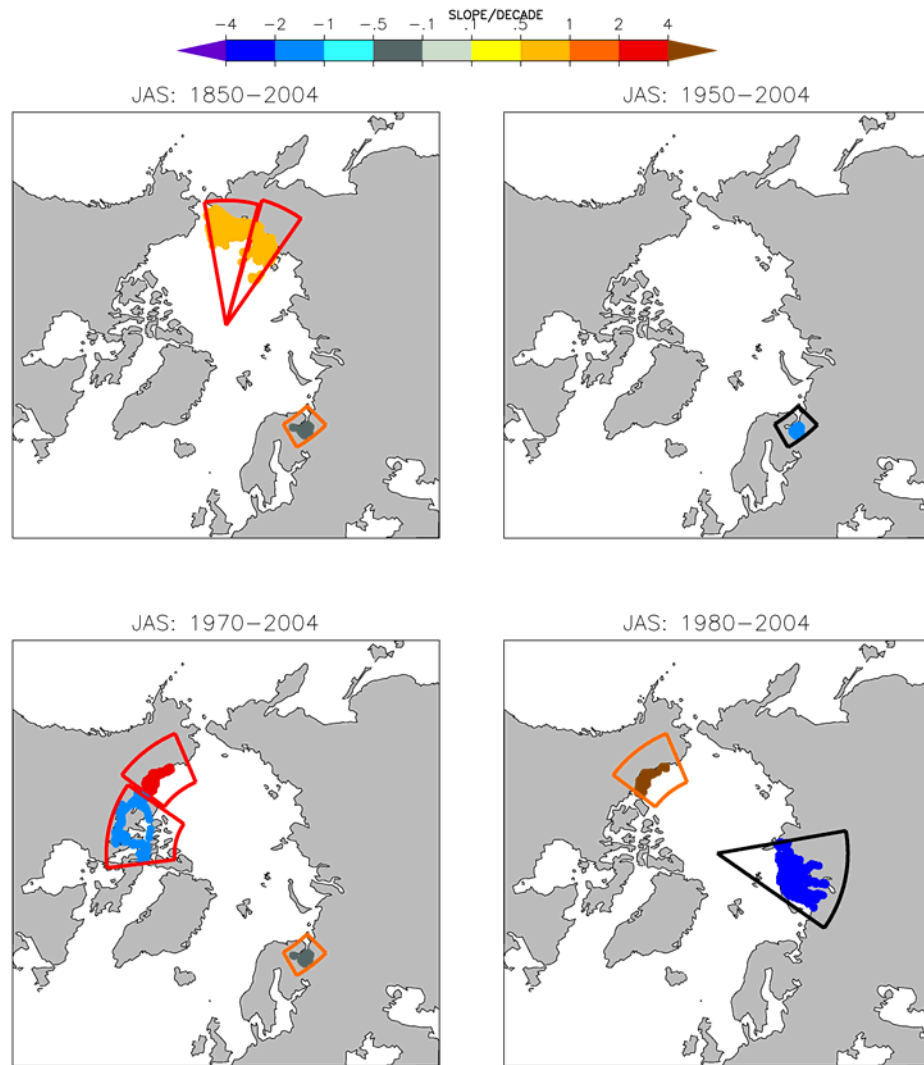


Figure 4. Statistically significant trends in 0-10m average summer (July-Aug-Sept) salinity on the continental shelves (defined by the 500m isobath) of the arctic seas. Trends are shown for 4 time periods, 1850-present, 1950-present, 1970-present, and 1980-present. Western Siberian seas show freshening trends over several time periods, while the East Siberian Sea shows a salinification trend over the past 150 years. The Mackenzie delta and Canadian Archipelago show a dipole anomaly over the past 30 years that might be related to advective changes associated with the Beaufort Gyre.

We see a distinct freshening in the White Sea and a possible recent freshening in the Kara Sea. In contrast, the Laptev Sea has no statistically significant trend, while the East Siberian Sea is getting saltier over the long term. These results are completely in keeping with the recent result of Peterson et al. (2002) who report increasing Siberian river discharge, especially in the western Siberian rivers. We also find an intriguing “see-saw” in the Mackenzie delta and Canadian Archipelago, which could be explained by changes in advection of Mackenzie river water forced by shrinking of the Beaufort Gyre. These results will be incorporated into a publication that is in preparation at this time.

M. Steele is responsible for guiding PHC research and advising on the trend analysis. W. Ermold is the main software programmer and web designer, and is the lead investigator on the trend analysis, which constitutes her Master's thesis in applied physics at the University of Washington.

WORK COMPLETED

Objective 1 (improving PHC): In FY03, we completed the update to PHC2.1 that was started in FY02. A notice was sent to all registered PHC2.0 users, and also to the general community via ARCUS' ArcInfo listserver.

Objective 2 (exploring temporal variability): This work is not yet complete. A paper is in preparation.

RESULTS

We have produced a state-of-the-art hydrographic climatology (PHC2.1) that is used by a variety of numerical modelers around the world. We are also learning about Arctic Ocean hydrographic trends. It seems that both river inflow changes and advection are affecting the state of arctic shelf seas on a decadal time scale.

IMPACT/APPLICATION

We have discovered the existence of long-term trends in the hydrography of the arctic seas. This will help us to remove this behavior from shorter-term variability that may be of more interest to Navy forecasters.

TRANSITIONS

We currently have 159 registered users of PHC2.1 from 15 countries. There are at least 13 published papers that cite PHC. Our database is used for numerical model validation, climate restoring, and initialization. It has also been used for theoretical studies of ocean circulation (Nishino, 2002). PHC is used in NavO's GDEM and NRL's MODAS climatologies for filling in the arctic seas of these global databases.

RELATED PROJECTS

The Arctic Ocean Model Intercomparison Project (AOMIP) is an international effort to directly test models against observed data and against each other. Currently we are running a coordinated experiment for the years 1948-2002, using PHC as model initialization and climate restoring. More information may be found at: http://fish.cims.nyu.edu/~holland/project_aomip/overview.html.

REFERENCES

- Antonov, J. I., S. Levitus, T. P. Boyer, M. E. Conkright, T. D. O'Brien, and C. Stephens, 1998: World Ocean Atlas 1998 Vol. 1: Temperature of the Atlantic Ocean, NOAA Atlas NESDIS 27, 166 pp.
- Boyer, T. P., S. Levitus, J. I. Antonov, M. E. Conkright, T. D. O'Brien, and C. Stephens, 1998: World Ocean Atlas 1998 Vol. 4: Salinity of the Atlantic Ocean, NOAA Atlas NESDIS 30, 166 pp.
- Environmental Working Group (EWG), 1997: Joint U.S.-Russian Atlas of the Arctic Ocean for the Winter Period [CD- ROM], Natl. Snow and ice Data Cent., Boulder, Colorado.

Environmental Working Group (EWG), 1998: Joint U.S.-Russian Atlas of the Arctic Ocean for the Summer Period [CD- ROM], Natl. Snow and ice Data Cent., Boulder, Colorado.

Nishino, S., 2002: Buoyancy- and eddy-driven circulation in the Atlantic layer of the Canada Basin, J. Geophys. Res., 107(C7), Art. No. 3071.

Peterson, B. J. et al., 2002: Increasing river discharge to the Arctic Ocean, Science, 298, 2171-2173.

PUBLICATIONS

Steiner, N., G. Holloway, S. Hakkinen, D. Holland, M. Karcher, W. Maslowski, A. Proshutinsky, M. Steele, and J. Zhang, Comparing modeled streamfunction, heat, and freshwater content in the Arctic Ocean, Ocean Modelling, in press, 2003.